SITE QUALIFICATIONS AND SITE SELECTION CRITERIA FOR THE GEOLOGICAL DISPOSAL OF NUCLEAR WASTES

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With the scientific community in general agreement that the deep geological repository is a practical solution to the problem of storage and permanent isolation of nuclear wastes, the question of where to locate the initial facilities arises. Identifying candidates for a repository site is analogous to--but on a much grander scale--the problems a city has in selecting a new site for its refuse or a site for a sewage disposal plant. In both instances, the health and safety of the public and the preservation of the wholesome aspects of the environment are considerations of concern. But, in the selection of a site for a new refuse disposal or sewage plant, the time of use of the site may be projected for as little as 10 years. In contrast, the selection of a site for a nuclear waste repository must take into account its potential for providing safety to people and the environment for up to such spans of time as a million years. In other words, up to the time when radioactive decay of the waste products has progressed to the point where the residual radioactivity is at about the same level as that found in nature.

Such a demand in site selection imposes much more than educated judgments. There must be firm evidence of the astuteness of such judgments, as derived from a defensible data base. A starting point in any scientific endeavor aimed at a specific objective is the establishment of criteria. The criteria developed to date governing the qualification and selection of sites for nuclear waste repositories, although not fully completed, have taken into account the thinking of many interests and disciplines.

One advantage of starting site selection by a set of criteria is that, immediately, some suggested sites can be ruled out--the old process of elimination to get to the core of the problem. To date, large areas of the country have been determined as not suitable for a deep geologic repository. Likewise, some geologic formations that formerly appeared as candidate sites have failed to qualify when tested against the initial set of criteria. And, as knowledge

through experience and experiments develop, the criteria themselves become more specific.

The preliminary criteria being evaluated today for identifying potential sites for a repository fall into the following broad categories: geologic, environmental, and socioeconomic. The last two are often referred to as nongeologic criteria. The environmental-socioeconomic criteria have important functions in the selection process, since no matter how appropriate the underlying geological formation, it may not be prudent, for example, to place a repository in a densely populated area or near a flood plain.

Many of the environmental-socioeconomic criteria under evaluation are of a potential exclusionary nature. The meaning here is that a repository could be precluded because of a Federal, state, or local law or regulation, or because of an obvious conflict with the present land use.

Ignoring for the moment the obvious conflict with existing land use, large areas of the country that might seem as potential sites for a repository--assuming the geological criteria were met perfectly--may still turn out not to be an optimum location for a repository. For instance, the concept of wilderness areas, as established by the Wilderness Act of 1964, recognizes the natural wild state of designated areas as assets worthy of preservation and these areas are to be left--quote--"where man himself is a visitor who does not remain". Designated wilderness areas could be therefore excluded from consideration as a repository site. In the development of criteria, then, the impact of these laws must be evaluated. This applies not only to areas under Federal control, but also to state lands designated to be preserved in the wild state by statutes, and to regional areas under joint state-Federal management where the preservation of the flora, fauna, and natural condition of the land is an objective.

Another Federal act that potentially excludes the possibility of location of a repository is the Wild and Scenic River Act of 1968. This act not only provides for the preservation of certain rivers in their natural wild condition, but also forbids man-made changes in their immediate environments. Clearly, land near the designated wild and scenic rivers may be excluded as a site for a repository, and these areas must be identified in the early stages of evaluating potential sites. Again, there are also state, regional, and local regulations pertaining to the preservation of

scenic rivers. Here also adjacent lands may be off limits for a nuclear waste repository.

The Endangered Species Conservation Act of 1969 and the National Wildlife Refuge Act of 1966--and their regional, state, and local counterparts--could further impact site possibilities. The same is true with the National Parks and National Monuments administered by the National Park Service within the Department of Interior and with the many state, regional, and local parks. Areas protected by the National Historic Preservation Act of 1966 and the Archaeological and Historic Preservation Act of 1974 could also potentially be disqualified. The Heritage Conservation and Recreation Service within the Department of Interior may lead to additional restrictions.

Conceivably at some time in the future if a particular site meeting all other selection criteria should infringe slightly on, say an excluded wilderness area, governmental action might be taken to allow an exception under the law. But in its selection studies, the Department of Energy is making every effort to avoid making recommendations that call for a compromise with the ideals of conservation and land and water preservation as established by Congress and the state governments.

All environmental-socioeconomic criteria, however, are not potentially legally exclusionary. Some are discretionary--and these are the criteria that call for economic judgments and social evaluations. Even though the geology of an area might make it technically ideal for the building of a repository, other social or economic factors may rule out the site.

Discretionary criteria are all concerned with the health and economic welfare of people in an area, as opposed to the esthetic, historic, conservation, and idealogical values associated with the exclusionary criteria already discussed. Discretionary criteria have been well defined; the list is exhaustive; and quite possibly as our knowledge advances, additional "go/no-go" considerations will be added to the list. In this presentation, I will touch upon some of the major, well-defined discretionary criteria--and discuss them from the negative standpoint; namely, what should not be done.

As the first example, the Office of Nuclear Waste Isolation would refrain from recommending to the Department of Energy, locating a repository site within limits of cities and populated regional areas. Such urban or semiurban areas support commercial

or industrial activities and are places of large monetary investment. It would not be desirable to disrupt the natural growth of the economies of such areas. The thinking at the present is that at least a five-mile buffer zone should be mandatory between an urban center and the potential site for a repository. A zone of this minimum width would permit the city to maintain its urban integrity, yet would hopefully not be so distant as to render travel hardships on repository workers who might live in the urban area. We must remember that while the citizens of some areas would not want such an installation in their environs, those of other areas would see the repository a welcome addition to their economy, providing jobs and increased business opportunities.

A second discretionary environmental-socioeconomic criterion pertains to ground water use. In locations where there are deep, extensively used ground water resources, a repository would not be desirable. This restriction has also been extended to include possible future domestic, industrial, or agricultural uses of ground water known to lie as deep as 500 to 1000 feet below the surface.

A third discretionary criterion applies to surface water. A deep shaft to an underground repository would not be practical in the flood plains of rivers or near large lakes or reservoirs. If an area is known to have been flooded within recent history, its suitability for a repository site needs careful consideration.

Topography is another discretionary consideration. Rugged terrain would result in high costs for site development and site access. There is no point in building in mountainous country if an equally appropriate site can be found on flatter lands. We consider that ground slopes greater than 500 feet per mile should be avoided. Rugged terrain may also be questionable from geologic considerations because of stability, hydrological, and other physical factors.

It would, of course, not be prudent to build a repository over areas where mineral resources--coal, petroleum, natural gas, various metallic ores, or other useful industrial raw materials--are known to abound. Areas over "worked-out" mineral deposits should be excluded for two reasons: First would be the danger of land subsidence because of the voids created by mining and drill holes, and second because at some future date man may wish to use the residual minerals left after the original exploitation became uneconomic. If only minor disturbance to the land has occurred,

such as, by surface mining or unfruitful drilling, the area could still be considered, with the recognized need for identifying and sealing any drill holes going more than superficially into the geologic structure.

Two other environmental-socioeconomic criteria should be mentioned. No sites should be considered that are close to military or commercial airports and runways. And, since repository operation will require electric power and transport of materials by truck and train, the site should be within a reasonable distance to power lines, railroads, and highways, so that connections to these systems can be made readily and economically.

The next and the most important broad category of criteria for site selection of a repository for nuclear wastes pertains to geologic factors. The evidence from all studies to date on the disposal of high-level radioactive wastes favors the deep repository in a suitable geologic formation as the most practical means for protecting present and future generations from the hazards of dispersed radionuclides. In simple terms, the idea is to lock up all radioactive wastes in a geologic formation deep within the earth in such a manner that the probability of the escape of any radionuclides to the surface and biosphere in the time required for decay to render the wastes innocuous would be negligible. We are now talking about physical and technological things, as opposed to environmental, sociological, and economic. And, whereas the foregoing discussion of environmental-socioeconomic criteria was primarily concerned with what "must not be done" or "should not be done", the geologic criteria are guides to "how we might do it".

First, it is apparent that the repository would have to be deep enough below ground level to prevent the isolated or stored materials from being subjected to surface disturbances. Some of the factors that affect the surface of land over long periods of time include wind scour, water erosion, glaciation scour, and meteorite impact. Studies suggest that wind scour is relatively insignificant, but that advancing continental ice could grind considerable depths of salt and rock in certain locations and formations. Major meteorite impact or a man-made explosion, as studies have suggested, would penetrate the surface by no more than 100 meters, although fractures may extend beyond this depth. A specified depth for a repository must include consideration of the probable penetration distances plus a margin for uncertainties.

A second geologic criterion pertains to the size and shape of the formation in which the repository would be located. It should be large enough for the repository and for an adequate buffer zone.

A criterion that is immediately apparent is the physical, chemical, and mineralogical properties of the host rock body and the geologic formations associated with it. We must know with precision the extent of the prospective host body, its nature, and the nature of surrounding materials. Core drillings will be necessary for laboratory analysis, for geophysical logging, and possibly for stress measurements and other tests.

One of the first hazards to a deep repository people think of when the subject is broached is: "How can you be assured an earthquake won't break the land open and expose radioactive substances to the atmosphere or to running water?" This concern can be extended beyond earthquakes to volcanic action and to the very slow movements of earth materials under high pressures and heat.

To deal with the need for long-term stability of the earth at or near the prospective site, several selection criteria have been set up. One states that "the repository should lie within a structurally stable geological block and not near a tectonic boundary".

The earthquake threat to a repository is covered by the criterion that states: "Faults along which rupture could occur must be avoided". This means very simply that we are not going to put a repository near a fault known to be seismically active or for which there is geomorphologic evidence of a slip in the last million years.

The minor seismic shaking that almost every area in the country experiences at infrequent intervals is not considered a problem. The underground and surface constructions of a repository can be designed to be resistant to these minor disturbances.

The possibility of volcanic action is given due consideration in the geologic criteria for site selection. One provision states: "Areas with abnormally high geothermal gradients or with evidence of relatively recent volcanic activity are possible candidates for future volcanic events and should be avoided." An area that has experienced volcanic activity in the past million years is likely to have further activity--and it is hardly more than common sense to avoid such spots.

Another criterion has to do with the soundness of the site for the excavations and structures--the same type of criteria one would have to deal with on opening a coal mine or building a skyscraper. We must be sure that the mechanical and geophysical properties and the state of stress in the host rock are such as to insure stability during construction and operation of the repository. A collapse of a shaft or tunnel could be disastrous, and we must admit that the public, which takes coal mine disasters and the collapse of buildings and stadiums in regretful strides, would be extremely sensitive to an accident in the construction or operation of a nuclear waste repository. The design of excavated vaults and the spacing of passageways must be such that the maximum stresses resulting from the cavities, thermal stresses, and the inherent state of stress in the wall rock are well below the critical value for the uniaxial compressive strength of the rock.

The broad category of geologic criteria in the selection of a site for a repository includes hydrological and chemical criteria, since these are, as one might say, "underground factors" associated with the geology that also determines the suitability of a site.

Because movement of water is the most probable means by which radionuclides might escape to the biosphere, the hydrological considerations are among the most critical in choosing a repository site. The aim is to assure that water transport will not move hazardous material to the surface in amounts and rates above prescribed safe limits.

Chemical criteria are also important in site selection, since the reaction of radionuclides with the geologic environment will have effect on the mobility of radioactive substances. The chemical nature of the host rock should be such that it is essentially nonreactive or only very slowly reactive with the contained radionuclides. Also, it should be immune to detrimental physical or chemical changes under the impact of radioactive heat and radiation.

Water, whatever its source--infiltrated from the surface, underground, reaction by-product, from crystal breakdown, etc.--is a factor to be guarded against, since it could act as the means of transport of radioactive substances to the biosphere. Also, the interaction of water with the repository rock could alter containment of radionuclides by affecting the frequency and size of fractures and creating cavities and channels. The extent of

such interactions would be affected by the mineralogy of the host rock, by thermal effects, the initial size and spatial distribution of pores, and by other factors.

In the time allotted for this talk, I have had to treat the various criteria for selection of a site for a geologic repository in a sketchy fashion. You will understand that each criterion discussed is treated in greater detail in the guideline documents we shall follow. Also, I have not mentioned all of the criteria.

We must look upon the selection criteria as guidelines that can grow, expand, contract, and be modified as we develop more knowledge through research and experience.

Only by admitting that we don't know all; that we're willing to probe for more knowledge; that we're amenable to learning--can we come up with selection criteria that will enable us to establish with confidence the site for the initial geologic repositories for nuclear wastes.